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Using `Hudson_Clearing.m` to model blast loads acting on finite-sized targets

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1 Introduction

In 1955, Hudson [1] developed a method for predicting the clearing relief acting on finite-sized targets subjected to blast loads. This predictive method has been automated into a `MATLAB` code called `Hudson_Clearing.m`, which allows the user to generate a series of keyword files for use with LS-DYNA [2] to evaluate the effects of blast wave clearing on a finite-sized, deformable target.

This document gives guidance on how to use `Hudson_Clearing.m`, as well as providing details of the underlying assumptions so the researcher understands the limitations of this method.

2 Algorithm

The algorithm for determining the load acting on the plate is implemented in the following way, which was first reported in [3]:

- The full ConWep [4] reflected pressure-time history, given the charge mass and stand-off, is applied to every node. It is assumed that the shock front arrives at every node simultaneously and is assumed to be uniform in magnitude (i.e. slant distance and angle of incidence effects are ignored). `Hudson_Clearing.m` gives a warning if the slant distance differs by more than 5% over the plate.

- For each node, the distances x_1 and x_2 to the free edges enable the Hudson clearing lengths, η_1 and η_2, to be evaluated. The corresponding pressure-time relief function is given by the superposition of each Hudson relief function, and is applied to each node with identical x coordinates.

- The same procedure is adopted for the clearing relief wave corresponding to the distance to the vertical free edge of the target and the reflection of the relief wave from the rigid ground surface. Both waves are applied to each node with identical y coordinates.

- Each node is therefore subjected to the superposition of three load curves; the reflected pressure and x and y components of clearing relief (the pressure is multiplied by the element area to give a load-time history).

When publishing academic work that has used Hudson_Clearing.m, please cite the algorithm outlined in Rigby et al. Clearing effects on plates subjected to blast loads. *Engineering and Computational Mechanics* 166(3): 140-148 (2013).

3 Files Written

The following section gives a brief outline of the keyword files written by Hudson_Clearing.m, in the order which they are written.

- mesh.k – this file contains all nodal and element information of the mesh. Hudson_Clearing.m allows the user to specify the mesh density by defining the number of elements along the length of the plate. Note: Hudson_Clearing.m does not allow the user to specify different element numbers in x and y directions, hence the mesh density will be the same in x and y dimensions. Node sets are also defined for boundary nodes. The top plate edge is given as set 1 and the edges are numbered clockwise thereafter (right = 2, bottom = 3 and left = 4). A node set containing all nodes is created with the setid = 5, to apply the uniform load to.
- xload.k – this file contains all load curves and load curve ids for x components of clearing.
- yload.k – this file contains all load curves and load curve ids for y components of clearing. Uniform load is also stored in this file under load curve id 5.
- nodesets.k – this file contains the node sets for each x group (node set ids start with 1001) and for each y group (node set ids start with 2001).
- loadsets.k – this file applies each unique load curve id to the corresponding node set id. The scale factor, is also specified based on the element area.
- segment.k – this file is not used when evaluating plate response to cleared loads, but contains all the information needed to analyse a plate under full reflected pressure using the *LOAD_BLAST keyword file.

4 Underlying Assumptions

It is worth noting that the Hudson method is subjected to the following underlying assumptions:

- The blast wave is plane and parallel to the target surface, with the direction of travel perpendicular to the target face. This implies that the target dimensions are small relative to the charge stand-off, or that the stand-off is large.
- The depth of the target is sufficiently large so that no diffraction waves arrive from the rear of the target. Rose [5] has shown these waves have negligible effect on the front-face load.
- The clearing wave propagates into stagnant air across the target face, i.e. no flow conditions exist in the direction of travel of the rarefaction wave.
- The velocity of the rarefaction wave is equal to the ambient sonic speed in air. This requires the incident pressure to be relatively low - Hudson judged that the assumption was reasonable for peak incident pressures of less than 300 kPa, i.e. $Z > 2.0$ m/kg$^{1/3}$.

- The clearing waves can be split into principal directions from vertical and horizontal target edges and can be superimposed to give the cleared pressure at any point on the target [6].
- The Hudson formulation is based on a positive phase decay parameter, b, of 1.0, with the positive phase of the blast load described as

$$p_r(t) = p_{r,max}\left(1 - \frac{t}{t_d}\right)e^{-b\frac{t}{t_d}} \tag{1}$$

  where p_r, $p_{r,max}$, t and t_d are reflected pressure, peak reflected pressure, time and positive phase duration respectively. Within the original report, however, Hudson [1] states that *'the errors introduced by a variation* $0.5 < b < 2.0$ *are minor... the effect of variation in b for values near unity is very small, becoming noticeable only as* $b \to 0$ *or as b exceeds 5'*.
- Fluid-structure interaction (FSI) effects are neglected and the reflected pressure is assume to be unaffected by target compliance. Further to this, the clearing waves are assumed to propagate along a flat, regular surface and the cleared pressure is also assumed to be unaffected by target compliance. FSI has shown to be important only for very low mass or very low stiffness systems, where the initial velocity of the target is comparable to the peak particle velocity [7, 8].

References

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